Asteroid Redirect Mission
An Update and Look Forward

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Why an Asteroid Redirect Mission?

- **Bringing an asteroid to cis-lunar space so that it could be sampled by astronauts in Orion is an excellent use of all the exploration capabilities being developed and provides a compelling early mission that advances exploration along an affordable and sustainable path.**
  - **The mission leverages the Space Technology Mission Directorate Solar Electric Propulsion (SEP) technology, including the advanced solar arrays and magnetically shielded hall thrusters, that feed forward to delivering cargo to Mars and the lunar vicinity.**
  - **The mission complements the Science Mission Directorate's Near Earth Object Observation program by expanding its capability.**
  - **The mission fully utilizes the early flights of SLS and Orion and early mission operations.**
  - **The mission also advances Exploration Extravehicular Activity, the International Docking System, Automated Rendezvous & Docking, and complex operations which all feed forward to future deep space and Mars exploration.**
  - **We also move a small planetary body from one place in the solar system to another, which is also the beginning of moving large objects around in deep space with SEP.**

Asteroid Redirect Mission

Identify

Asteroid Identification:

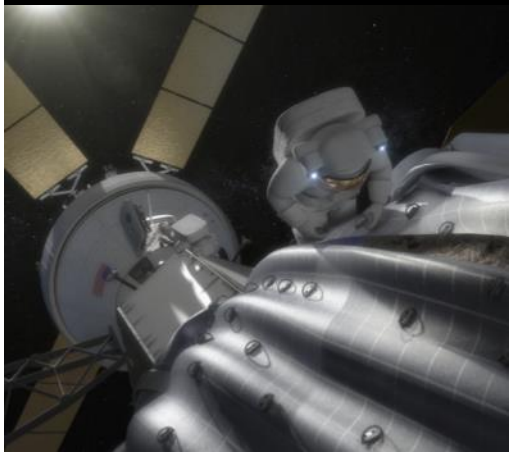
Ground and space based near Earth asteroid (NEA) target detection, characterization and selection

Redirect

Asteroid Redirect Robotic Mission:

High power solar electric propulsion (SEP) based robotic asteroid redirect to lunar distant retrograde orbit

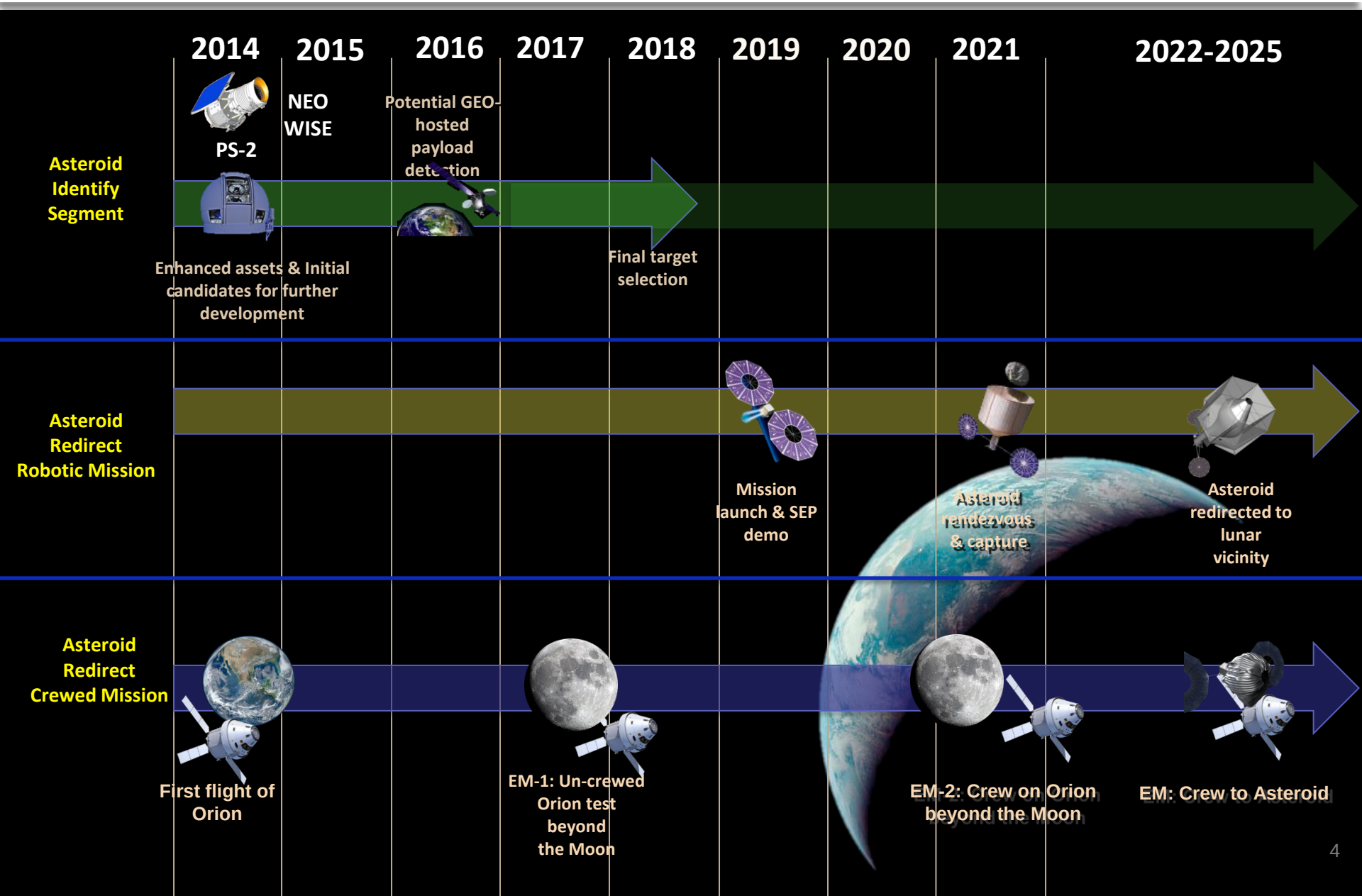
Explore



Asteroid Redirect Crewed Mission:

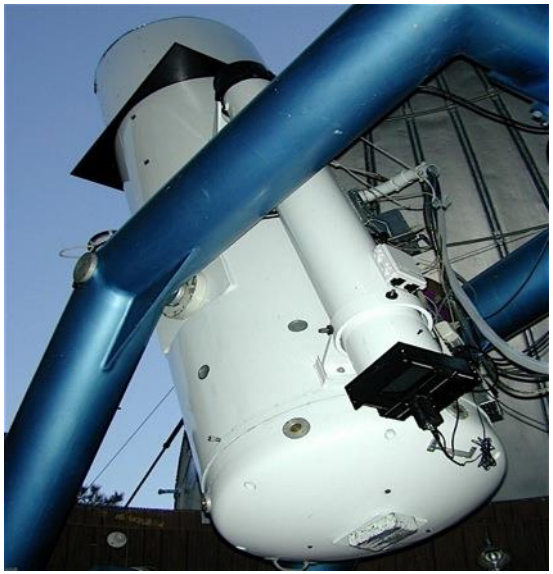
Orion and Space Launch System based crewed rendezvous and sampling mission to the relocated asteroid

ARM Schedule



Near Earth Object Identification (a few elements)

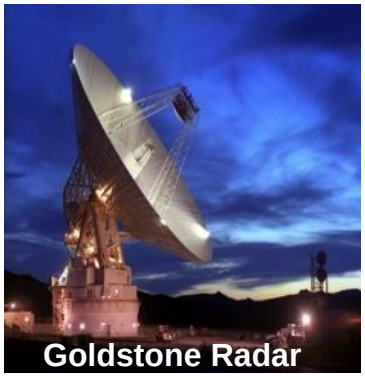
Catalina Sky Survey



University of Arizona – Tucson

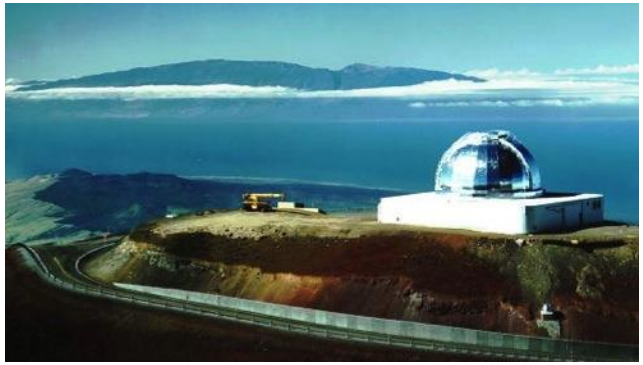
NEOWISE reactivated and dedicated to NEO Search & Characterization

Utilize Radar (Goldstone and Arecibo) increased time for NEO observations.



NASA InfraRed Telescope Facility (IRTF)

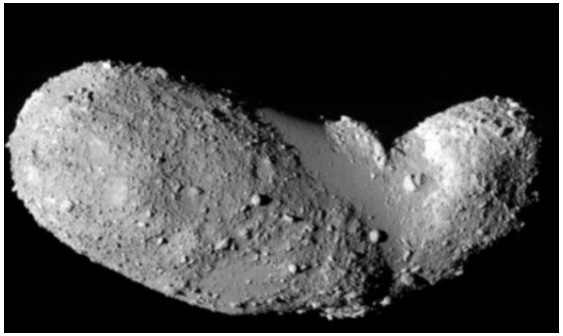
- Increase On-call for Rapid Response.
- Improve Instrumentation for Spectroscopy and Thermal Signatures.



NASA Asteroid Redirect Mission Internal Studies Completed

Reference robotic mission concept

- To redirect a small near Earth asteroid and potentially demonstrate asteroid deflection
- Study led by the Jet Propulsion Laboratory

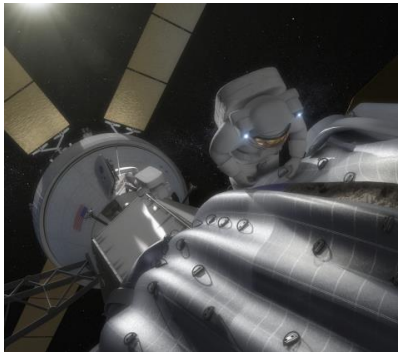


Alternate robotic mission concept

- To redirect a boulder from a larger asteroid and potentially demonstrate asteroid deflection
- Study led by the Langley Research Center

Crewed Mission

- Crew rendezvous and sampling for either concept
- Led by the Johnson Space Center



Robotic Concept Integration Team comparative assessment

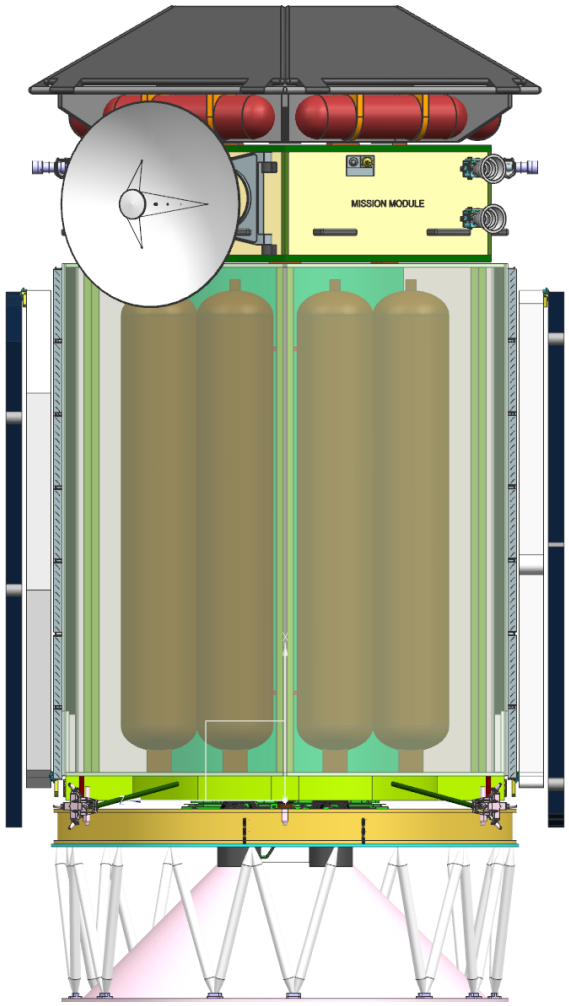
Robotic Mission Spacecraft Reference Configuration Key Features

Capture Mechanism
- Flight heritage instrumentation
- Inflatable capture bag

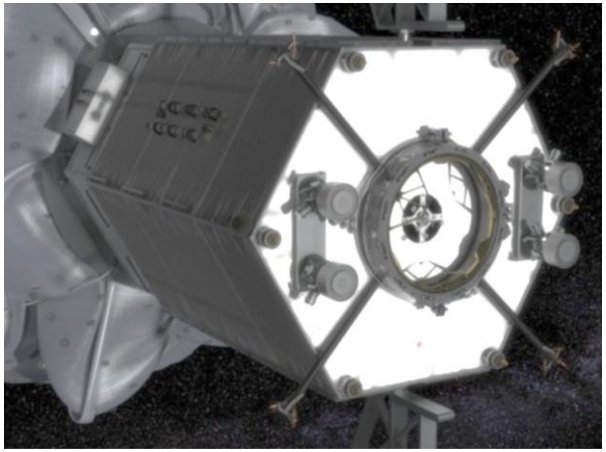
Mission Module
- Flight heritage avionics
- Simple Interface with SEPM

SEP Module
- Compatible with STMD solar array technology at 50 kW
- EP derived from STMD Hall thruster/PPU technology
- Xe tanks seamless COPV with at least 10 t capacity
- Unique structure design
- Conventional thermal control
- Conventional reaction control subsystem

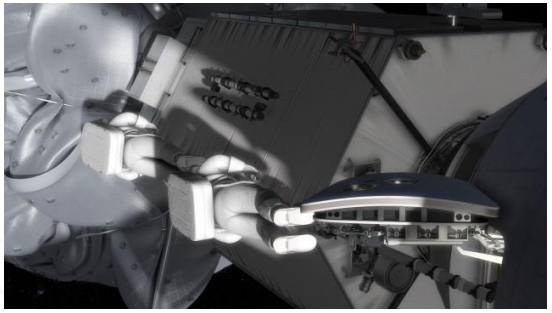
Launch Vehicle I/F
- Compatible with 5m fairings
- Unique adapter depending on LV selected



Orion docking I/F

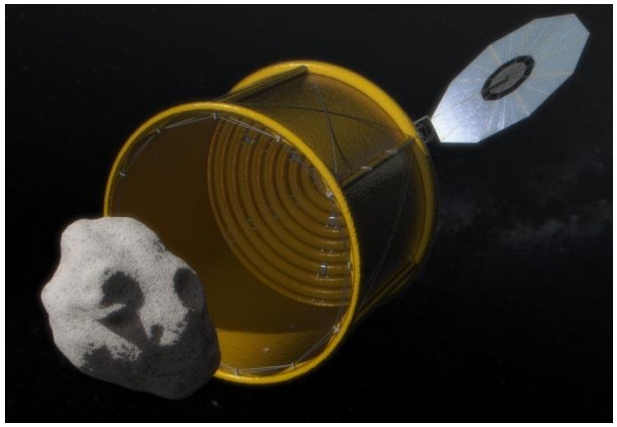


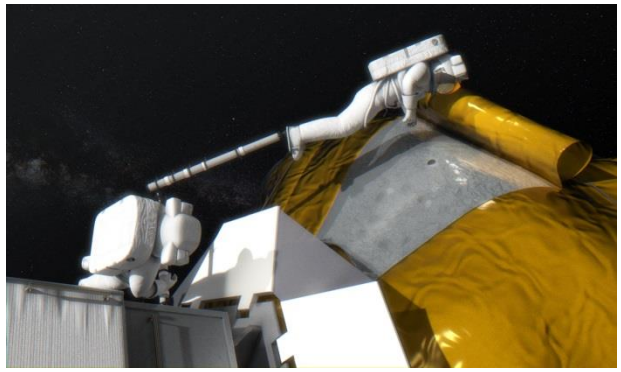
Crew access path



Asteroid Redirect Robotic Mission
Whole Small Near-Earth Asteroid Capture Concept (Option A)

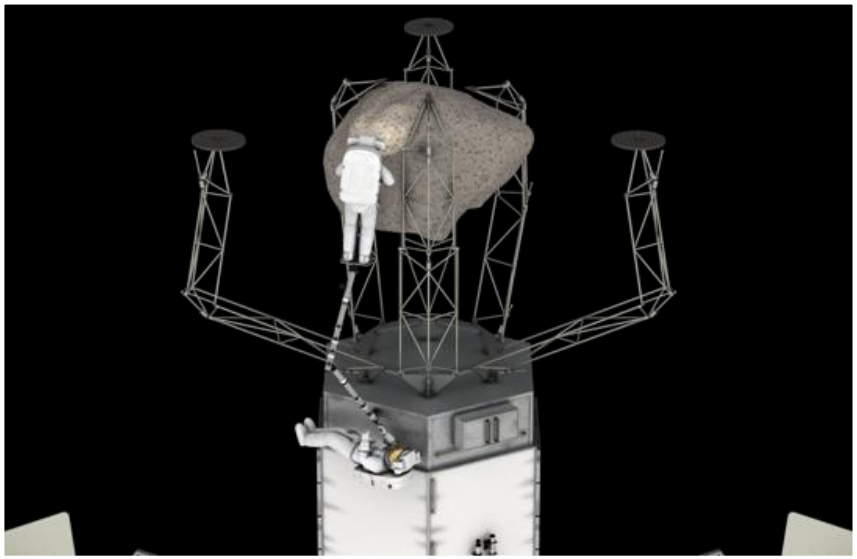
- **Rendezvous with small less than 10 meter mean diameter Near Earth Asteroid (NEA)**
  - **Capture <1000 metric ton rotating NEA**
  - **Demonstrate planetary defense techniques**
  - **Maneuver to stable, crew accessible lunar Distant Retrograde Orbit (DRO)**
- **Candidate target is 2009 BD**
  - **5 meter mean diameter and < 145 metric tons**
  - **Launch mid-2019*; Crew accessible after 2/2024**
- **Additional candidate targets expected to be discovered and characterized at the rate of approximately 5 per year**
- **Other candidates under evaluation**
  - **Recent Spitzer observation of 2011 MD which is crew accessible in August 2025**
  - **2014 BA3 crew accessible in early 2025**
  - **2013 EC 20 crew accessible in late 2025**

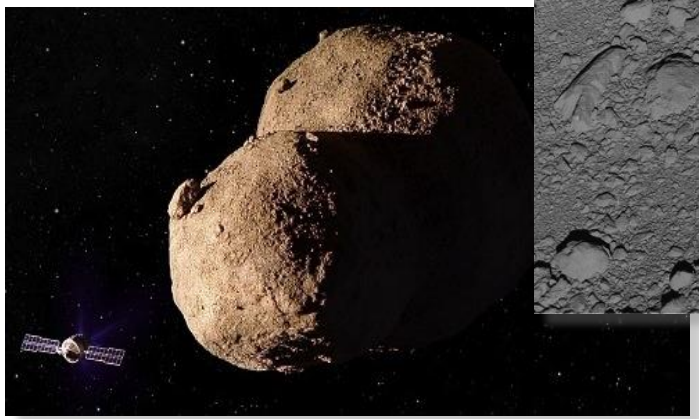


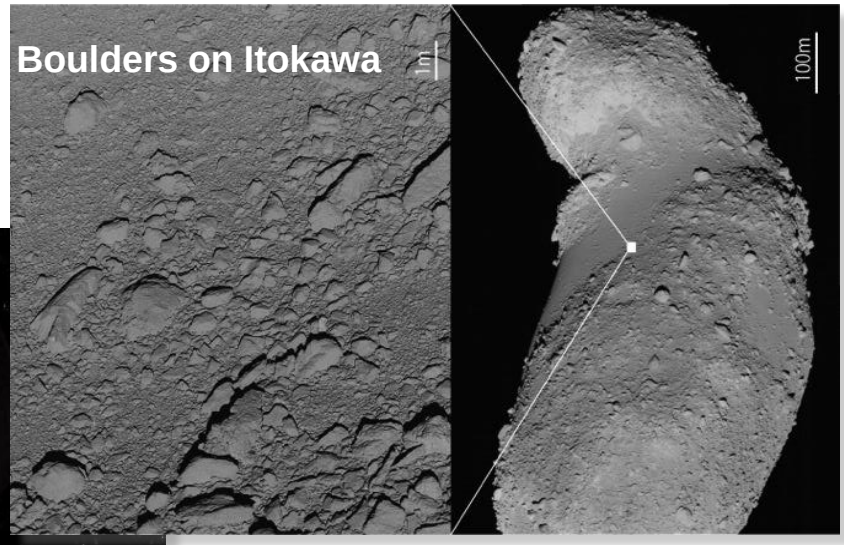


Larger Asteroid Boulder Capture Concept (Option B)

- **Rendezvous with a larger (~100+meter diameter) NEA**
  - **Collect ~2-4 meter diameter boulder (~10-70 metric tons)**
  - **Perform deflection demonstration(s) and track to determine effect**
  - **Return boulder to same lunar orbit**
- **Candidate asteroid Itokawa**
  - **2-3 meter, 18 ton boulder to DRO in 2025 (2019 robotic mission launch)***
- **Other targets to be characterized by in situ observation and crew accessible in DRO in 2025**
  - **Bennu by OSIRIS-Rex**
  - **JU3 by Hayabusa 2**
  - **2008 EV5 by radar or other means**







Robotic Mission Profile Comparison – Points of Departure

Phase/Activity	Small Asteroid (2009 BD)		Robotic Boulder (Itokawa)	
	Date/Duration	Xenon Use	Date/Duration	Xenon Use
Launch	**June 1, 2019**		**June 20, 2019**	
Outbound Leg	1.4 years	899 kg	2.2 years	4,020 kg
Asteroid Rendezvous & Proximity Ops				
Arrival	**Jan. 3, 2021**		**Sept. 11, 2021**	
Characterization & Capture	30 days		51 days	
Capture Phase Margin	30 days		18 days	
Planetary Defense Demo	1 hour		262 days	170 kg
Margin (Missed Thrust, Prox Ops)	30 days		69 days	30 kg
Departure	**Apr. 3, 2021**		**Oct. 16, 2022**	
Inbound Leg	2.2 years	858 kg	2.5 years	1,830 kg
Earth-Moon System DRO Insertion	Feb 15, 2024	127 kg	August 2025	70 kg (TBR)
Earliest Crew Mission	**Feb-May 2024**		**Aug-Sept. 2025**	
Assumes Heavy Lift Launch Vehicle (Delta IV Heavy/Falcon Heavy)	Xe used: 1,884 kg Asteroid Return Mass: 30-145t (2.6-7m mean diameter)		Xe used: 6,230 kg Boulder Return Mass: 11 t (1.8 m spherical, 2.3 m max extent*)	

* At 2,2,1 aspect ratio

Broad Agency Announcement (BAA) Objectives

- **Build upon RFI inputs and recommendations from the Asteroid Initiative Ideas Synthesis Workshop.**
- **Engage external community in system concept studies, technology development activities, and studies of potential future partnership opportunities to reduce mission risk.**
- **Provide alternate system concepts for consideration during ARM Mission Concept Review to be held early 2015**
  - Asteroid Capture Systems: Concepts including using deployable structures and autonomous robotic manipulators.
  - Rendezvous Sensors: Rendezvous sensors that can be used for a wide range of mission applications including automated rendezvous and docking, and asteroid characterization and proximity operations.
  - Adapting Commercial Spacecraft for Asteroid Redirect Vehicle: Commercial spacecraft design, manufacture, and test capabilities that could be adapted for development of Asteroid Redirect Vehicle.
  - Studies of Potential Future Partnership Opportunities for Secondary Payloads: Studies for secondary payloads on either Asteroid Redirect Vehicle or Space Launch System (SLS).
  - Studies of Potential Future Partnership Opportunities for the Asteroid Redirect Crewed Mission: Areas such as advancing science and in-situ resource utilization, enabling commercial activities, and enhancing U.S. exploration activities in cis-lunar space.

ARM Concepts Near Term Schedule

• Request for Information Release	Jun 18, 2013
• NASA Mission Formulation Review	Jul 30, 2013
• Ideas Synthesis Part 1 (RFI responses)	Sep 30, 2013
• Robotic Concept Integration Team Kicked Off	Oct 25, 2013
• Ideas Synthesis Resumed (RFI responses)	Nov 20-22, 2013
• NASA Internal Integrated Status Review	Dec 17, 2013
• Tasking Request for External Community Special Studies	Jan 8, 2014
• Spitzer Observation of 2011 MD	Feb 9, 2014
• NASA Internal Mission Concept Development Review	Feb 19, 2014
• Broad Agency Announcement Release	Mar 21, 2014
• Asteroid Initiative Opportunities Forum in Washington DC	Mar 26, 2014
• STMD Solar Array Systems development Phase 1 complete	Jun 2014
• BAA Awards	NET Jul 1, 2014
• STMD Integrated Thruster performance test with 120V PPU	Sept 2014
• HEOMD MACES EVA end-to-end mission sim Complete	Sept 2014
• BAA Interim Reports Due	Oct 31, 2014
• HEOMD Orion Exploration Flight Test 1	Dec 2014
• BAA Period of Performance Ends	Dec 31, 2014
• Robotic Mission Concept Review	Early 2015